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NOVEMBER, 1929

Featuring

**The Economic Application
of Aerial Surveys**



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THE ECONOMIC APPLICATION OF AERIAL SURVEYS

BY J. F. BAGLEY, JR.*

(Presented at a meeting of the Boston Society of Civil Engineers on September 25, 1929)

IN response to a request that I present a paper before the Boston Society of Civil Engineers, giving my version of aerial surveying and its importance to engineering, I hesitated to do so because I am not an engineer, but feeling that the viewpoint of a salesman might be of interest, I agreed to do this.

During the past two years I have been connected with the largest, most complete, aerial surveying unit in the country. Thus it is natural that I should have heard a great many people discuss this new and increasingly popular method of mapping. Each speaker has endeavored to impress his audience with the complications which are embodied in this method. To me the important advantage of this method lies in its simplicity.

When an experienced pilot and photographer are equipped with an aerial photographic plane and the proper photographic instruments, it is a comparatively simple and everyday occurrence for them to map large areas. The experimental stage of completing the photographs and ratioing them to fit into one map is past, and it requires only the use of proven methods by competent aerial engineers.

The uses of this proven method of map making is the phase to which aerial mapping companies are turning their attention. Unless these maps

* Fairchild Aerial Surveys, Inc., Boston, Mass.

can serve some economical advantage there will be no place for them in the American scheme of business.

The problem of using the maps must be studied by engineers in all branches. An engineer with a problem to solve may readily see where aerial maps can be used, or, if he will explain his problem to an aerial engineer, they may between them find a solution. It is quite impossible for the aerial engineer to be familiar with all of the problems that can be solved by the use of an aerial map, for he has no way of finding out what the problems are unless they are brought to his attention. He has, of course, found many uses for these maps, but there are many other uses which only the engineer with a problem to solve in his own particular field of work can find.

The engineer always has been in the forefront of every scientific development. It is the engineer who has abolished our frontiers; it is the engineer who made the preliminary survey, adventured to the outposts of civilization, and, in short, mapped the world; and these maps, both in reconnaissance and in detail, have been the foundations upon which has been reared the intelligently planned structure of modern development. What, then, is more natural than to find that even in this inventive age the engineer again leads the van in modern scientific development.

It is to the advantage of every engineer, regardless of his field of work, to assist in developing new uses for this universally accepted method of making maps.

Have you ever realized what a tremendous task the company that introduced this work took upon itself when it attempted to introduce this new method, making use of the airplane, which at that time was a novelty to almost every one?

Several years ago, when an aerial photographic salesman endeavored to show an engineer that a territory could be accurately mapped from an airplane flying several thousand feet above the ground, he was faced with almost unbeatable arguments, for the salesman knew very little about aerial surveying. He had been told that by using maps made by this method certain things could be accomplished. In theory these things were true, but no one knew whether or not they were practical. In most cases the salesman knew very little about the engineer's problems, and as a result used tactics commonly known as "high pressure selling."

After several well-known engineers had studied the problem and had acknowledged that large areas could be mapped in a comparatively short time, and in most cases at considerable less expense than a ground survey, some engineers were found who were willing to experiment. Others

believed that if this method were applied it would rob them of a large part of their work. This, of course, was not so, and it soon became apparent that if this method were intelligently applied it would become a new tool with which they could extend their field of work and lengthen their day.

On the other hand, the salesman started out with an idea, which in most cases he did not fully understand himself. When he could not think of an answer to any of the baffling questions being constantly put to him he bluffed, and could always tell a story about the remarkable achievements gained by the use of aerial surveys in the remote wilds of Canada.



FIG. 1. — OBLIQUE AERIAL PHOTOGRAPH

Showing North Station Terminal of the Boston and Maine Railroad and Vicinity

The hypnotized client could visualize a day of rest, during which his work would be entirely done from an airplane flying thousands of feet above the ground. The client had contracted to make a map of an area of, say, ten square miles. While he was dozing in his office an airplane would fly over this area, and in some way or other obtain a map which would show everything within that area to an accurate scale.

Property bounds would be shown, and even the property owners' names would appear on the property, and in some cases the client actually believed that the water and sewer lines would be shown in their proper places. In other words, the results obtained by the use of the aerial method of surveying were very much overstated.

This kind of selling, even though it was the worst kind of misrepresentation, had its advantages and effects. The expectant client received a very clear picture of his ten square mile area, showing only those things that could actually be seen from the plane. The engineer, realizing he had expected things that were impossible to obtain, immediately set his highly trained imagination to work and began to visualize the real possibilities of these pictures. He found that the pictures were to a comparatively accurate scale. He also found that trees, ditches, stone walls, old wood roads and innumerable other landmarks that would be very hard to locate on the ground were shown on the aerial pictures.

During the next few years aerial photographic mapping gained steadily in favor with the engineer. Its progress was very rapid, and there was every reason to believe that its further development would make it adaptable to a great many branches of engineering.

To the best of my knowledge the first extensive and successful use of aerial maps for a commercial purpose was in making timber surveys. In mapping large areas in Canada it was found that by employing this new method more accurate estimates could be made, and the time required for making these estimates was only a fraction of the time formerly needed. Ellwood Wilson, Civil and Forestry Engineer of Canada, recently stated that "It takes a party of eight or ten men a month to survey fifty square miles." In order to complete this large area in such a short time it is necessary that men of long experience be employed in that particular kind of work. All kinds of hardships were endured, and frequently the men were attacked by swarms of insects that made it impossible to make correct notes.

This condition is obviated when flying several thousand feet in the air, and it is possible to completely map an area of this size in one day. As proof of the acceptance of this method, James D. Lacy & Co., probably the largest forestry engineering company in the country, has recently announced its connection with an aerial surveying company in order to give their clients a complete service. Through past experience it has been found that the maps needed for forestry surveys consist of contact prints at a scale of 1 inch equals 800 feet, which can be very readily used with a stereoscope and a rough mosaic at the same scale.

Another tried and proven use of this work is in transmission lines and railroad locations. Right-of-way engineers have found these maps indispensable. These maps have not only assisted the engineer in planning the location of his line, but have proved to be very valuable to the right-of-way purchaser. Executives and larger operators, who were exceedingly skeptical when aerial photography was first suggested, are today requesting a map of this kind before making their preliminary plans.

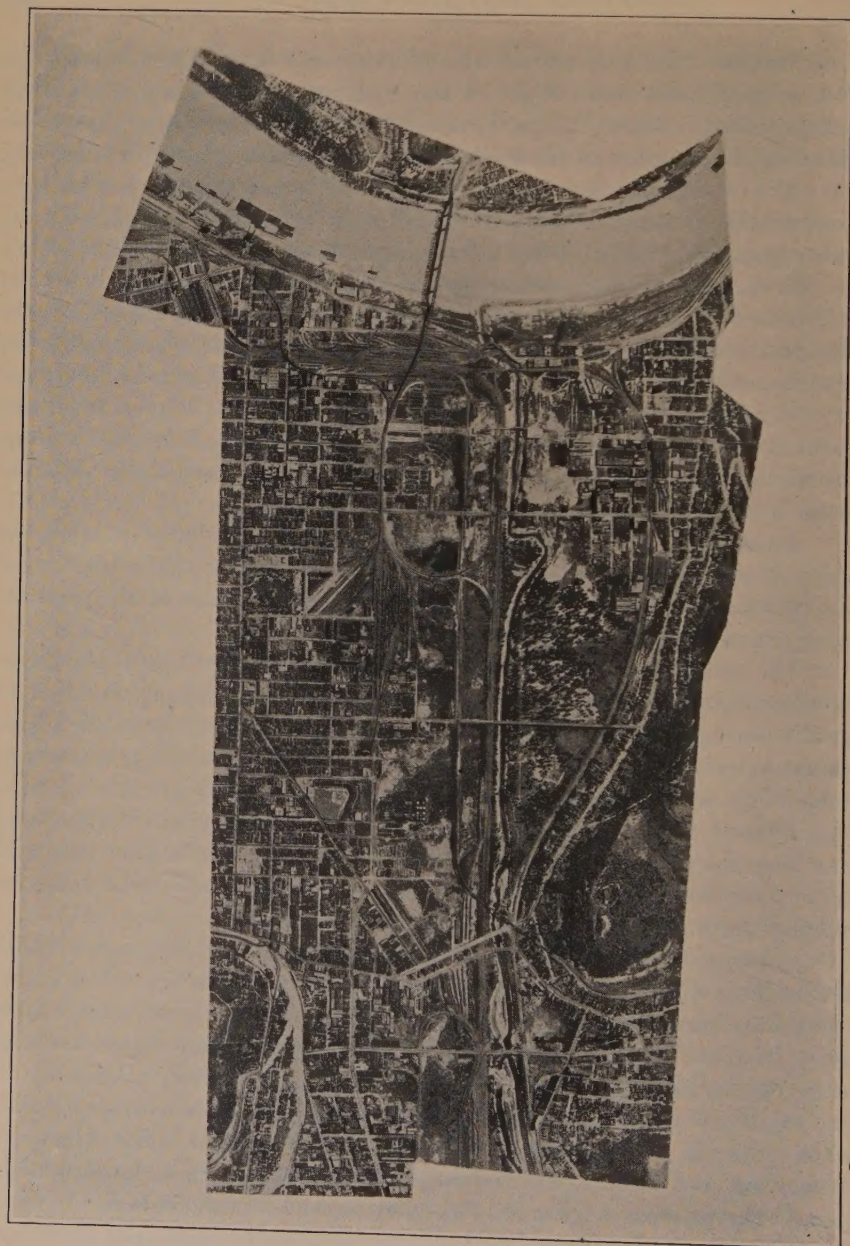
In the projection of transmission lines the power company knows only the two terminal points of the line to be built. Naturally the cheapest route to follow in theory would be a perfectly straight line between these two points. Strange as it may seem, however, there are so many obstacles to such a plan that in most cases a longer and more indirect line proves the more economical. On account of the high voltage carried it is imperative that the line be kept a reasonable distance away from farmhouses, barns and other buildings.

Areas which are heavily timbered must be avoided if possible, as the cost of clearing the right of way and damages for timber destroyed are considerable items. The law does not allow a line of this kind to cross cemeteries, therefore they must also be avoided.

The usual ground survey for a transmission line will show the alignment and profile of the route, topographical data for the region adjacent to the route, railroads, roads, lanes, property division lines, and telephone, telegraph and power lines crossed by the route of the transmission line. The survey data will also record the property owners' names. It will be noted that the results of the survey apply only to the territory touching the proposed route, and that although considerable time and effort have been put in the survey, the survey may have to be repeated in case the route of the line has to be changed later.

Contrast the work of obtaining the usual preliminary survey with the method of obtaining the same result by an aerial survey. If weather conditions are favorable the aviator and photographer may ascend miles away from the vicinity, and within a few hours may have mapped a large area, descended, and stored their airplane in its shelter. Probably no one at all saw them as they flew along, over two miles above, and if they were noticed, any comment was quickly forgotten. The films are developed, and in two or three days contact prints are at hand, and in two or three weeks a mosaic of the entire region is available.

If you examine them you will see that each cultivated field and wooded lot is clearly discernible, — things that are not shown on the government map. You will find roads and lanes meandering around in a different fashion than those on the government maps, and where the



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FIG. 2.—MOAIC MAP OF RAILROAD YARDS' AT CINCINNATI, OHIO

This Survey was made to illustrate a "Progress Report"
and was originally flown at 1"=400'

quadrangle map shows a small dot we count several scattered buildings, and even find buildings where none is indicated on the government map. You look closer and count the trees in an orchard and the corn shocks in the fields. You compare the contour lines on the government map with the aerial prints, and hilltops and ridges seem to stand out. You can even see where the rains have washed gullies in the hillsides. So you pick out the hilltops and ridges that skirt the wooded areas and draw in the proposed route of your line so that it misses farm buildings and orchards and schoolhouses, and decide that you have a tentative location for the line.

By use of aerial maps the companies' right-of-way agents have been able to get out into the field and secure options or easements for right of way without any preliminary field work. It has been possible by the use of the aerial photographs to show clearly to the various owners the location of the proposed line without going out and tramping all over the fields. The advantages to all parties of this method of purchasing right of way can be readily appreciated, and in practice it has resulted in considerable saving.

Another very valuable feature of these photographs is that they provide a detailed, accurate, permanent and easily accessible record of what is on the ground. The records of a field survey would at the best be very meager compared with an aerial photograph, and would consist of little more than a center line, fringed with a sprinkling of survey data. The information on the aerial photographs will be of the utmost value during the period of construction, enabling the distribution of material to be worked out to the best advantage, which is itself quite a problem in an isolated bush country where transportation costs mount up to a considerable figure. It is also expected that construction camps and material dumps can be located to the best advantage by the use of the photographs.

Power lines differ from railroads in that they can be placed over much rougher country, and it is not so necessary to follow grades and contours, but as many of these lines pass over very valuable cultivated lands and thickly populated areas, it becomes necessary to pay great attention to the choice of right of way.

In some instances it is possible for the power company to avoid the purchase of expensive property, and the saving on options alone may pay for the aerial photographic survey several times over. Should the power company send parties to survey the country along the projected line to determine the properties crossed and the right of way to be purchased, it would not only take time and be very expensive, but would often defeat the purposes for which it was intended. It is only human nature for

property owners to boost the prices of their land when they see a party of surveyors in the vicinity. Also, in order to be sure of obtaining the right of way for the final location, it often occurs that many options are taken of property not affected by the line at all. The more modern method is to determine the location of the line by aerial photographs, and obtain options on the properties to be crossed, and then send the surveyors out to run the line and make the final location.

The material usually furnished for right of way and railroad location, and that which has been most advantageously used, are contact prints at a scale of 1 inch equals 800 feet, a mosaic map at 1 inch equals 400 feet, or atlas sheets at 1 inch equals 400 feet.

Through careful study and experimenting other uses have been found to which the aerial method of mapping can be applied.

Maps for planning and zoning, consisting of contact prints at 1 inch equals 800 feet and a wall map, or mosaic, at 1 inch equals 400 feet, have been used with a high degree of success. For committees made up of citizens having little or no technical training, it has been found that through the use of these maps these committees have been enabled to do very effective work.

Traffic committees, highway departments, park departments and reclamation boards, and, in fact, many groups requiring the use of maps, are using aerial maps to help solve their particular problems.

For tax work the aerial map has proven its value through practical application; for example, five years ago aerial maps were made of Middletown, Connecticut. A very careful check was kept on these maps, for this was the first municipality mapped for this purpose.

There were 1,896 buildings discovered that had previously escaped taxation. Proof of the successful use of these maps is evident in view of the fact that since Middletown was mapped, in 1924, over 12 per cent of the entire State of Connecticut has been mapped for tax purposes.

Boston is at present being mapped for the Board of Assessors. The scale of the maps usually delivered for tax assessment are as follows: contact prints at 1 inch equals 500 feet or at 1 inch equals 600 feet; enlargements at 1 inch equals 100 feet and a mosaic at 1 inch equals 200 feet. The map for the city of Boston will go a step beyond the usual requirements in that the maps of the congested section of the city will be to a scale of 1 inch equals 50 feet.

Aerial engineering has been so universally broadcast, explained and applied that I am not going to take up your time by referring to the methods of making an aerial survey, but will, rather, take up with you the fundamentals of a protective check of the aerial survey as it

comes to your hands as engineers. First, in your contract make sure that it specifies emphatically the amount of overlap of photographs, both in sequence of taking and in overlap of adjacent strips. For all practical purposes the sequence of overlap, that is, overlap on the long



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FIG. 3. — HALF SCALE REDUCTION OF CONTACT PRINT
SHOWING A SECTION OF JAMAICA, LONG ISLAND

Originally flown at a Scale of $1'' = 200'$; may be enlarged to
 $1'' = 50'$ without Loss of Detail

edge of the exposure, should stipulate a minimum of at least 60 per cent. I may add that in congested areas with tall buildings 80 per cent overlap as a minimum makes for the ideal product. The overlap of adjacent strips of photographs should be stipulated as a minimum of 50 per cent,

and will also state that 60 per cent is the ideal minimum for congested areas. If the index map shows less than the stipulated overlap, the contracting aerial engineering firm should be called upon to immediately re-photograph such areas upon the next photographic day, thereby compensating for lengthening or decreasing shadows caused by the lapse of time.

The contracting company should show proof of correction of tilt; for instance, if at the moment of exposure the plane has rocked out of horizontal position and the camera has not been corrected in position so as to maintain a true verticle to the terrain, it is obvious that one edge of the photograph will be at a different scale than the opposite edge, which will cause trouble and grief to the engineer using that photograph in the field or as an enlargement. Up to a certain degree of tilt this can be corrected by rephotographing, during which process the negative is tilted in the reverse angle to the same amount that the camera was tilted at the moment of exposure. This is a correction by compensation.

The hours for photographing should be clearly defined in the contract, so that, particularly in congested areas, the photographs are taken when the sun is at its highest point, thus giving the shortest shadows.

Where a sharply defined line separates the business district from the residential and outlying areas it should be specified that these two areas should be considered as separate units, so that, for instance, the congested area could be photographed upon one or closely succeeding days, as the lapse of a week's time at certain periods of the year will completely change the aspect of terrain, and thus the resulting product will appear as a patchwork job.

In dealing with enlargements the finished job should be carefully checked to see that the enlargements have thrown up from a rectangle whose center is coincidental with the optical center of the photograph, as this is the portion which is the true vertical projective under the center of the lens. For this reason it is very desirable to employ a camera which has a glass pressure plate as part of its equipment, as not only does this pressure plate hold the film absolutely flat at the moment of exposure, but also permits the engraving of a minute cross upon its center, which shows in the photograph as the true optical center of the aerial negative.

In conclusion, gentlemen, I think you will all agree when I say that I believe the aerial survey, like the airplane, is here to stay. The survey has found its place and is in many ways serving an economical purpose, both in the saving of time and cost. The yearly total of business of the larger aerial survey companies is constantly increasing, which is sufficient proof that more engineers and laymen are becoming air-map minded.

Discussion

PROF. CHARLES M. SPOFFORD:* My connection with aerial surveying is extremely recent and was brought about by a request to serve as engineering adviser to the Assessing Department of the city of Boston, which involved, among other duties, the preparation of specifications for an aerial survey of the city for the use of the assessors. This survey has not been completed; in fact, it has hardly been begun; hence it is not possible for me at this time to present the methods used and the results obtained. I shall, therefore, confine my remarks to the reasons why the Assessing Department decided to obtain an aerial map of the city, and to an explanation of certain of the clauses of the specifications for this work.

Strange as it may seem, there is in existence no accurate map of the entire city of Boston. The Board of Survey which was established in 1891 to survey the unimproved portions of the city and prepare plans for their development made an accurate triangulation survey of the city as a whole, and determined co-ordinate locations of controlling points, the co-ordinate axes being referred to the dome of the State House as an origin. With this triangulation survey as a basis, detailed surveys were made of portions of the city lying southerly and westerly of the built-up district, which included the Back Bay Fens, Brighton, West Roxbury and Dorchester. Forty-six per cent of the city area as it then existed was covered by these surveys. Hyde Park, recently annexed to the city, was, of course, not included. The Board was discontinued in 1895 by Mayor Collins on the grounds of economy.

In addition to the Board of Survey maps, a good map exists of South Boston, but there is no map of known accuracy covering the congested down-town district, where property values are greatest; moreover, the Board of Assessors has never had available for its use a set of complete and accurate lot-and-block maps, giving dimensions of all lots and showing all buildings. In this respect it is far behind nearby New England cities, such as Cambridge and Springfield, as well as some of our larger cities, including New York, Baltimore, Cleveland and Chicago.

It was because of this lack of accurate maps and other data, and the great expense and time required to obtain such maps by field surveys, that the Assessing Department decided to have an air survey made. In order to secure bids for such a survey, specifications for the necessary work were prepared by K. C. Newhall, under the supervision of the speaker, the work was advertised, bids received and the contract awarded

* Hayward Professor of Civil Engineering, Massachusetts Institute of Technology, and Consulting Engineer.

to the low bidder, the Curtiss Flying Service of New England, at a bid price of \$14,712.

No specifications were available for consultation although such specifications may have been written by other cities; the specifications were prepared, however, only after consultation with others who had made use of aerial surveys for other purposes and with representatives of several airplane survey companies.

Some of the features of the specifications may require explanation. The necessity for greater precision for the thickly built-up portion of the city than for the outlying districts is obvious and accounts for the division of the city into Districts A and B, the former covering the more congested and valuable portions of the city.

The scale required for the negatives from which the contact prints are to be made is fixed for District A at 250 feet to the inch, which, with a camera of 20-inch focal length, specified as the minimum focal length to be used, requires flying at an elevation of 5,000 feet for this portion of the city. The contact prints for District B are to be made on a scale of 500 feet to the inch, requiring flying at 10,000 feet elevation.

The distortion of a photograph from a true scale increases in proportion to its radial distance from the center of the lens, hence to obtain an accurate map it is necessary to discard a considerable portion of the contact print made from each negative. In order, therefore, to get accurate results, the negatives must overlap each other both in line of flight and in parallel lines, and only the central portion of each contact print be utilized. The amount of overlap for this particular survey is stated in the specifications. The mosaic map mentioned in the specifications is a map prepared by combining the central portions of the contact prints by discarding the distorted portions, and is the basic map from which the complete maps for assessing purposes are to be made by enlargement.

Enlargement sheets to be made from the mosaic maps are of a size suitable for use in the assessors' office. These maps will show all existing streets (from plans now available, it is often impossible to tell whether streets actually exist or are merely paper streets), and all existing buildings, which may possibly include some buildings not shown on present plans and not taxed; at least, such has been the result in some cities where aerial survey has been made.

While the maps thus prepared will not show property lines except where buildings cover the entire parcel, as is the case in congested districts, and will furnish total block areas only with the degree of precision which scaling of the map permits, they will provide a set of lot-and-block maps to a uniform scale for each of the two districts which will be suitable

for recording all existing information as well as all future information obtained from surveys, property transfers, building permits and other sources available to the assessors. They will also serve as a means for checking with some degree of exactness the total areas contained in all city blocks.

For a complete valuation of the buildings each will have to be examined in the field and the cubicle contents and character determined, as was done in Cambridge some years ago, and is now being done in Chicago; but with the aerial maps available, the recording of such information will be much simplified as well as the checking of it to insure that all buildings have been included.

In addition to their value to the Assessing Department, these aerial maps should prove useful to other city departments dealing with traffic, zoning, city planning and other similar problems. They will also probably be in considerable demand by real estate and fire insurance interests.

The specifications for the aerial survey previously mentioned are given on pages 483-487.

FREDERICK N. FOWLER:* The subject of aerial surveys is no longer a new one. The work of the pilot, the photographer and the maker of the mosaic map has developed from a crude, hit-or-miss type of work to a stage in which experience, individual skill and technical computations enable them to follow through the various steps of their work with a familiarity that has the appearance of simplicity itself.

The engineer is not interested so much in the production of the photographic map as he is in the adaptability of the photographic map for his purposes.

The many varied uses that have been made of aerial surveys indicate that their ultimate use and adaptability is limited only by the user's imagination and his ability intelligently to apply the aerial survey to his work.

Different types of work require greater or lesser degrees of accuracy in the map. To attain a high degree of accuracy it is necessary to spend much more money for time and labor than is required for a low degree of accuracy. The engineer, having a certain project in mind, knows what degree of accuracy is necessary to produce maps sufficiently accurate to furnish him with the information he desires. For example, a hydraulic engineer desires to make a preliminary study of a watershed of considerable area. For this purpose it is not necessary to have a map that is extremely accurate, but it is very desirable to know within reasonable limits the area of the watershed, the per cent of watershed that is wooded,

* Consulting Engineer, Boston, Mass.

the per cent of the watershed that is under cultivation, and whether the soil is sandy or rocky, whether the stream flows through deep, narrow valleys with steep sides, or whether the stream flow is through a gently rolling country; and many other details of a more or less general nature.

All of this information may be easily obtained from aerial surveys and at a commensurate expense. The area can be photographed at scales varying between 1 inch equals 1,000 feet and 1 inch equals 2,000 feet, or more, and the individual pictures be assembled to form a rough mosaic, that is, a mosaic where the pictures are brought by laboratory processes to approximately the same scale and then laid down by matching.

The usual contact print is approximately 7 by 9 inches, so that each individual photograph will cover in excess of two square miles with a scale of 1 inch equals 1,000 feet, and in excess of eight square miles with a scale of 1 inch equals 2,000 feet.

Such a mosaic places the entire watershed before the engineer, on his own drafting table, in his own office, where he can study it in its entirety more leisurely, in comfort, and with greater concentration than can be done in the field.

By the use of the stereoscope he can study the topography of the watershed and determine the best probable sites for dams and reservoirs, whether they be for power purposes or for community consumption.

This type of map is not particularly accurate as to scale, but it is, nevertheless, reasonably so, and its reconnaissance value far exceeds the really moderate expense entailed in its production, especially where there are no U. S. G. S. sheets obtainable. Maps thus made are usually of the lowest degree of accuracy in scale that the aerial map maker produces, and the lowest in price.

Aerial surveys for tax map purposes are made of varying degrees of accuracy, depending largely on the value of the property to be surveyed, and consequently on the ability of the municipality to pay for the added expense necessary to produce accurate maps.

Aerial maps for country and village property are generally flown at a scale of 1 inch equals 400, 600 or 800 feet, depending on the expenditure that the town feels warranted in making. Customarily the pictures of the outlying or farming sections are enlarged about two diameters, and the congested, or village sections, enlarged three or four diameters.

I might say right here that to fly an area at 400 feet to the inch requires four times as many pictures as to fly the same area at 800 feet to the inch, and that the cost of doing the work varies in nearly the same proportion.

Property of this character does not warrant a very large expendi-

ture for the making of tax maps, and so it is well to limit the control furnished to the aerial survey company by the engineer or municipality, and from which the map maker computes the scale of the individual negatives, before enlarging to the scale desired in the finished product. Control for aerial surveys of this character is generally limited to railroad location maps, state highway maps, or such other maps and surveys as are readily available.

For tax maps of the larger cities it is necessary that the aerial survey work be produced at a larger scale and with a much higher degree of accuracy, and at a consequently greater expense.

The work now being done for the city of Boston is being produced under rather ideal specifications, and excellent results may be expected. The control being furnished by the city to the aerial survey company, according to the specifications, will be of a high order, and the mosaic produced should be of an equally high degree of accuracy.

However, where the ratio prints cover areas of varying elevation it is likely that additional control measurements will be furnished so that they will scale accurately on the average plane of the area which they cover. For instance, the control data to be furnished, under the specifications, in the area bounded by Beacon Street, Massachusetts Avenue, Southampton Street, Dorchester Avenue, Broadway and Charles Street to Beacon Street are sufficient for either a mosaic or a ratio print. In the Beacon Hill section, however, the ratio prints should cover only comparatively small areas, and should have control distances for each print if it is desired that the area on each print shall be to an accurate scale.

For transmission line work several types of control are furnished to the contracting aerial survey company.

Where the line covers a considerable distance, and it is possible to locate triangulation stations on the photographs, this should be done so that the triangulation distances may be used for overall horizontal control.

Such control tends to prevent accumulative errors in ratioing from print to print, and keeps the mosaic substantially true to scale throughout its entire length and breadth.

Triangulation stations are, generally speaking, at a somewhat higher elevation than the general datum plane of the territory being surveyed.

It is well, therefore, to furnish such additional control as may be had from railroad and highway plans which traverse the surveyed area in whole or in part, as such plans usually show points easily identified on the negatives between which distances may be scaled.

Such control points are considerably below the elevation of the triangulation stations and approximately at the elevation which is general to the territory covered by the picture.

In the absence of railroad, highway or other existing maps or plans it is necessary to measure between points easily identified on the photograph in a manner excellently specified in the Boston specification.

Aerial survey maps for transmission line purposes are seldom more than 1 per cent in error so far as scale is concerned, and almost never more than 2 per cent in error, and such accuracy is sufficient for the purposes for which they are to be used.

Water works, water power, railroad, highway and transmission line projects all require a certain amount of property boundary location.

Maps for tax purposes require property boundary locations complete.

There is, therefore, a certain similarity to work done by the locating engineers upon the aerial ratio print or mosaic in each one of these different types of work.

Physical property boundaries, such as stone walls, fences, ditches, hedges, tree cuttings and streams, show clearly on good aerial photographs, and may be easily distinguished.

The usual method followed in bringing the particular property lines into prominence is as follows:

The engineer's assistants take the contact prints into the field, inquire of the owner where his property bounds are, and he, being familiar with the territory and seeing only a picture, is able to identify his boundary lines thereon. The engineer's assistant then follows around the outline of the property, marking it with a pencil.

If there is a portion of the property line that is marked only by heaps of stone, or by stone bounds, instead of fences, walls, ditches, etc., his problem is a little more difficult, yet when he finds such bounds he can nearly always locate them on his picture by reference to two or more objects that are identified on the picture, and so he goes from one property to another, marking the property lines of each individual owner on the photograph, from which, when he returns to the office, he transfers the data to the ratio prints or to the mosaic, depending on which is used.

On the ratio prints or mosaic the property lines are usually drawn with India ink or water color. A yellow water color is easily applied, easily removed, and at the same time clearly marks the property lines on the mosaic.

Property lines on a farm 200 acres in extent were thus recorded in two hours.

Sometimes the engineer's assistant will discover unrecorded maps

which he is able to borrow in order to establish the property lines on the mosaic.

In this manner one of my assistants one afternoon obtained a map giving property lines of nearly four square miles. Of course this was an unusual bit of luck.

Line-drawn property maps enlarged or reduced by pantograph to the scale of the mosaic seldom fit the mosaic exactly, but the physical features of the boundary lines show on the photograph, and it is easy to adjust, or, as engineers say, "fudge" the line-drawn plan to match the photograph.

However, the errors in the individual parcel outlines are very slight, and it is only a minimum amount of "fudging" that is necessary to bring about coincidence.

For all practical purposes, even though the line-drawn maps have been "fudged" slightly, the *tout ensemble* of the mosaic is substantially correct, and it is only necessary to make a ground survey of such portions of the property lines as it is necessary to have absolutely correct.

About five years ago I was given an order to make a study of a proposed transmission line route about forty miles long.

I decided this would be an excellent opportunity to make a test of the benefits that might be derived from aerial surveys, and after further investigation placed a contract with a large aerial survey company to do the work.

In the same contract I included a portion of a transmission line route which was in the process of acquisition, and where it had been very difficult to obtain a satisfactory location.

Three tentative locations had been made by means of ground survey, but they had all been discarded for one reason or another.

The location of the right of way on each side of the difficult area had been established and purchased.

The usual preliminary ground surveys had been made preparatory to running the center line of a fourth location by the time the mosaic of this section was delivered by the aerial survey company.

This mosaic covered about six lineal miles of the right of way, and the difficult section was about four miles long, so that the mosaic not only covered the difficult section, but about a mile on each side of it.

The center line of the satisfactorily located right of way was superimposed in yellow water color upon the mosaic.

In the same manner the fourth proposed location in this section was also superimposed upon the mosaic; an inspection of these superimposed lines indicated that the fourth line was satisfactorily located.

A further study of the mosaic also indicated that by discarding some of the right of way already purchased an equally satisfactory right of way might be located and the total length of the right of way reduced by 1,200 feet. The center line of this last-mentioned location was staked on the ground from data taken from the mosaic. It proved to be satisfactory, and, as indicated on the mosaic, 1,200 feet shorter. If the mosaic had been available from the first much of the ground survey work would have been unnecessary, considerable time would have been saved, and less title work required. This right of way is 150 feet wide and about thirty miles long, and has been located and acquired through a rather congested territory. It provides for two lines of steel towers, each line to carry two circuits, vertical suspension, 110,000 volt power lines.

Disregarding the survey and title examination economies, and considering only the reduction in cost of the one power line at present constructed, approximately five times the cost of the aerial survey has been saved by reduction in the length of the line as a direct result of the use of the aerial photographic mosaic. When the second line is constructed the saving will, of course, be doubled.

Every possible location for transmission line rights of way may be laid out on the mosaic, carefully studied, and the most economical route selected. Doubtless economies are thus effected in right-of-way property costs, but such economies are, generally speaking, small as compared with the much greater savings resulting from smaller angles, fewer towers and reduced length of conductors, due to the engineer's selection, from the study of the mosaic, of the shortest and most direct, feasible route.

Comparison of the amount and extent of ground survey traverses, where aerial survey methods have not been used and where aerial survey methods have been used to assist in locating transmission line rights of way, indicates that aerial survey methods reduce the ground survey work by about 50 per cent. The saving thus effected will often equal the cost of the aerial survey.

Comparison of the amount of title work required for transmission line rights of way on jobs where aerial surveys were not used and on jobs where they were used indicates that a reduction of approximately 50 per cent of the work of the title examiners has been effected.

Dollars and cents savings in title work vary materially between sparsely settled and thickly settled territories. Seldom will the saving be less than the cost of the aerial survey, and in thickly settled sections the saving effected is sometimes four to five times that cost.

Intelligent application of aerial mapping to any work requiring "area surveys" will result in savings in time, money and labor.

Methods of application will vary, depending on the type of project for which the survey is made, and on the imagination and inventiveness of the engineer in devising ways and means to utilize the aerial maps to the best advantage.

KARL R. KENNISON:* My discussion will be essentially a brief outline of the experience of the Metropolitan District Water Supply Commission to date with work of this character. Two contracts for aerial photographs have been completed during the last three years, the first of which was made with the Fairchild Aerial Surveys, Inc., dated November 22, 1926.

The exact area to be photographed under this first contract comprised about 100 square miles, which was shown on a plan, the outline being indicated by an irregular line. The contract provided that the negatives should be the property of the Commonwealth, and that they should be delivered upon demand. These were of the same size, 7 by 9 inches, as those required by the contract for the Boston survey referred to previously. The 7-inch dimension was in the direction of flight. The optical center of each photograph is marked by a cross in each picture, and the overlap is at least 50 per cent, so that the optical center can be located on each adjoining photograph.

A complete set of contact prints, with semi-matte finish, was required by the contract. Glossy finish has not been used because it is easier to mark on the semi-matte finish. The scale of these contact prints is approximately 1 inch equals 1,200 feet, which corresponds to a flying height of two to two and one-half miles above the ground. The actual scale varied because of the marked variation in the elevation of the ground surface which consisted, in the main, of a broad, flat valley, which in some places was three to four miles wide, with steep sides, which were frequently 400 feet high.

Enlargements were specified to be furnished, as required, at a scale of 1 inch equals 400 feet, and the control for determining the scale of the enlargement was to be furnished by the Commission.

Completion of the making of exposures and contact prints was required before the 15th of December of that year. In the case of snowfall a certain extension of time would be permitted because snow renders these photographs almost useless for our purposes, a statement which probably holds true for almost any city work because of the loss of detail. No specific provision was made with reference to unsatisfactory pictures caused by smoke of forest fires, which, in fact, did cause some trouble.

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However, the general provisions of the contract required that the photographs shall be satisfactory, and the contractor therefore did re-photograph a part of the area in a satisfactory manner after the fires subsided. It is somewhat difficult in the case of a heavily wooded area to get a combination of good flying conditions and no fires within the area.

A total of 278 contact prints were furnished by the contractor. Of these, 107 prints were selected which would cover the whole area satisfactorily and show what was desired.

A mosaic was not required to be furnished by the contract.

Mr. Fowler has already called attention to the fact that there are two kinds of mosaics, — one, a matched mosaic, decidedly fudged, just to give a picture; and the other, which he calls an "exact mosaic." My belief is that it is impossible to make a satisfactory mosaic to scale by the method which he has mentioned for a country as hilly as the area which I have described.

The particular requirements of the work of this project led to the conclusion that if any mosaic were to be made it should be made up by the engineers on the work, who were familiar with the specific problem and could determine just what parts of the separate contact prints were of interest. No mosaic has yet been made of the entire area, and if one is made it is doubtful if it will be possible to make it on an accurate scale because of the hilly country involved, the hill portions of the prints being found at different scale from that of the valley portions. There is no question but that the results in some respects in that particular country were disappointing, and yet, in other respects they were more than gratifying. Mr. Hammond, who has actually made detailed use of the prints in the field office, will tell more of this.

The second contract was for the photographing of a strip rather than an extensive area, and was awarded the following spring, on March 30, 1927, to the same contractor. This included surveys of four rivers, of particular interest, having a combined length of fifty-six linear miles. The specifications were similar to those of the first contract, except that the scale of the negatives was to be approximately 1 inch equals 800 feet (instead of 1,200), and the scale of enlargement was to be 1 inch equals 200 feet (instead of 400). Very little use was made of the enlargements, because the contact prints furnished so well all the information necessary.

No photographs were to be taken when the water surfaces were frozen or during high water conditions. The contract called for completion before May. The total number of contact prints furnished was 196,

of which 69 were selected, furnishing sufficient information in the area for our purpose. No mosaic was required by the contract.

The first contract included the purchase of a mirror stereoscope. This, when used with the photographs in which the overlap was 50 per cent, made it possible to view two such pictures and obtain the effect of relief, the hills and valleys and all objects standing out remarkably. The use of this instrument has not been extensive, being confined to a study of some details.

One use of aerial photographs, which I hope will be elaborated upon by others who are more familiar with the details than I am, is the accurate location of straight lines, such as transmission lines. Last year, at a meeting of the society, reference was made to "radial" control, a term used for the process of locating such lines and objects correctly on the prints.

The only line that can be drawn on any print, which will be a straight line in the field, is a radial line through the optical center of the print. This assumes that the airplane is horizontal when the picture is taken. One or two degrees from the horizontal is not enough inclination to affect the results materially, and it is apparently feasible to maintain the plane sufficiently level to be practically certain that any line drawn from the center of the print is a straight line on the ground, for the reason that it is in a vertical plane.

For example, consider three prints which actually overlap. It is possible to locate the optical center of each print upon each of the other two, and just as accurately as it is possible to draw with a fine ruling pen. After all three centers have been thus located very accurately, radial lines may be drawn through them, the same line appearing on two adjoining prints. These lines extended form a triangle which may be plotted on any large scale, as a triangulation. The result is just as accurate as could be obtained with any surveying instruments and careful plotting for this particular triangle, but no other lines on the contact prints can be so used except a radial line.

For the accurate location of some other point — for example, a house that appears on two or all three of the prints — the following may be done. A radial line is drawn on each print through the center and the house. The intersection of these lines extended will be the exact location of that house on the scale of the enlarged triangulation. Furthermore, on any contact print there may be laid off the correct radial distance to the house, but it may not coincide with the location of the house on the picture if the country is hilly.

A perfectly straight line, such as a transmission line, may be drawn

across the sheet on the enlarged scale of this triangulation, but when the same line has been reproduced on any of the three prints, and made to pass through its proper points that show on the prints, it will not necessarily appear straight on the print in hilly country, but actually will be a straight line on the surface of the ground.

N. LEROY HAMMOND: * The last speaker mentioned one contract which the Metropolitan District Water Supply Commission entered into with Fairchild Aerial Surveys, Inc., during the latter part of 1926. This contract was for the aerial survey of the area to be affected by the proposed Swift River Reservoir, and was in preparation of extensive ground surveys of that area.

The science of aerial photography is relatively new, and while many engineers have been interested casually and are always anxious to view the aerial photographs, yet they are inclined to be somewhat skeptical as to their practical value, particularly where one user will dwell on the accuracy of results, while another will claim that but little accuracy can be obtained. From the experience in the Swift River Valley the aerial survey is a valuable asset to the work of the field engineer.

The contract called for the photographing of some one hundred square miles of area. The Swift River Valley is characterized by a series of high ridges from three to four miles apart, running generally in a northerly and southerly direction. Scattered through the floor of the valley are also numerous hills rising sharply 500 to 700 feet above the river level. For the purpose of photography, the natural course for the flight of aircraft was in a northerly and southerly direction along the axes of the various valleys. With the contract calling for an overlap of 50 per cent there resulted a large number of contact prints of the entire area. The photographs were taken at a flight elevation of between 10,000 and 12,000 feet above sea level, which resulted in contact prints 7 by 9 inches, with a scale of approximately 1,100 feet to the inch. The contract also provided for enlargements to a scale of 1 inch equals 400 feet, with control data for such enlargements to be supplied by the engineers of the Commission. Aside from the Massachusetts topographic maps, there was little data available for proper control because actual ground surveys had advanced but slightly when the aerial photographs were taken. Furthermore, as the object of aerial photography was to aid the ground survey, it became necessary to secure control data within the shortest possible time.

An attempt was made to scale from the United States topographic maps the distances between intersections of highways to compare with

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the photograph of the same highways shown on the contact prints, but as many prints showed but small stretches of such highways this method was found to be impracticable. Finally, distances from definite points on each contact print, such as known houses or other outstanding features, were actually measured by roughly dragging a long chain between these points, generally along the highways. The scale of various sections of each contact print was then approximately determined and a ratio for enlargement evolved. Considerable variation of scale of different portions of each contact print were found, due largely to differences of from 500 to 600 feet in ground elevation with resultant camera distortion. The contact prints were particularly clear, and it was decided that in general little would be gained by having enlargements, and consequently only a few of the contact prints were enlarged by the photographic process. Had the area been more uniformly of the same elevation, it is probable that enlargement ratios would have been more easily determined and an actual aid would have resulted in having all photographs to the same scale.

The uses of the contact prints have been many. The area which was photographed will ultimately be acquired by purchase or otherwise, and involves a considerable task in the examination of title of real estate holdings. In the case of three of the towns in the valley approximate real estate maps were made by use of the contact prints. Each print was carefully studied and every indication of a property line was photographed to a skeleton map of the town. The resultant plot was then taken into the field in company with an assessor of the town, and actual known property lines were designated as such on the plot. Owners' names were inserted as encountered. Thus a somewhat crude map of each town was developed generally by two men in about two weeks. This gave a working map for a systematic search of real estate titles by title examiners, and without doubt has been of considerable value in this work.

As the ground survey of topographical features and real estate survey have progressed, constant use has been made of the contact prints in the checking of plots of these surveys. We have all had the experience of plotting field notes with an uncertainty of the interpretation of proper connection between points located. With the contact print at hand an immediate check on such plotting can be made, thus facilitating the proper final execution of the map.

One of the speakers has mentioned the use of contact prints in the field by parties engaged on real estate survey. A similar use of these prints has been made in the real estate surveys in the Swift River Valley.

Party chiefs have taken the prints into the field, and by questioning local residents have gained a great deal of information as to the exact location of property lines. In a wooded country it often happens that even owners are uncertain as to their exact lines. A careful inspection of good contact prints will indicate a line of difference of timber growth of but few years, whereas on the ground no difference in growth may be observed. By calculating the azimuth of these indicated lines from lines of known location, the field party can generally, in a relatively short time, determine a somewhat difficult property line and corner. Without the data shown on the contact print similar locations might take several days of searching.

The contact prints have also been of considerable assistance in the analysis of real estate deeds. In one instance a lumber operating company had released their holdings by option. The tract of land had originally been made up of three parcels. Upon the checking of the deeds which conveyed these parcels there was one which could not be made to fit into the larger tract. It had been carefully drawn by metes and bounds, and but little could be found of its history. A close examination of contact prints was made in order to see if any parcel might be observed which would fit the troublesome deed. At a considerable distance away from the large tract to be conveyed was found a picture of a plot of ground which appeared to fit exactly. A field party was sent out to make a ground survey of the new area, and it was found that it did cover the deed in question. It finally developed that an early owner had held deeds for five parcels of land, one of which was included in the tract of the lumber company, and another in the parcel surveyed. It appeared that the wrong deed had been copied and unintentionally a parcel had been conveyed with no connection to the tract desired. The parties adjusted the matter by means of an exchange of quitclaim deeds.

In order to show the progress of acquisition of real estate a general map of the valley was made on a scale of 1 inch equals 1,000 feet. For the compilation of this map data was pantographed from the contact prints, using as a control the survey sketches shown in the Massachusetts Town Boundary Atlas, which show water courses, houses, stone walls and fences in the immediate vicinity of the town corners. With the knowledge of the exact geographical position of the corner, together with orientation of an actual aerial picture of the physical features, a good control for the large map was established. The detailed portions of the map were somewhat crude as to accuracy, but in the absence of extensive ground survey well served the purpose.

On this particular work the aerial survey has paid for itself many

times, even though but little utilization has been made of photographically enlarged prints. The contact prints have been practically in daily use during the progress of the ground surveys.

IRVING B. CROSBY:* I have found a way in which aerial photographs are of use to the geologist and indirectly to the engineer. In engineering geology work in a poorly mapped or unmapped country aerial photographs are a great help. While making an extensive geological investigation in northern Quebec, where there were no good maps, I found it very difficult to know what sort of country I was dealing with, but when aerial photographs of the region were available they solved a great many problems and were a very good substitute for maps. The photographs do not completely take the place of maps, but, on the other hand, they show a good many things which the maps do not show, as, for example, the location of ledges. Of course, if the photographs are taken in winter the ledges do not show and the value of the pictures to the geologist is greatly reduced. Both the vertical and oblique pictures are useful. For becoming familiar with a region the oblique pictures are to be preferred, because they cover so much more country and reveal the topography better; but for studying the details of a special area the vertical pictures are better. Most of the pictures are taken from high altitudes, but it would be of great advantage to the geologist if they were taken at low altitudes, showing more details of rock outcrops.

The aerial photographs also help in studying the structure of the rocks. It is sometimes possible to see in the picture structural features which it would be very difficult to find on the ground on account of the dense bush which hinders field work. Strange as it may seem, I have found air pictures of use in predicting conditions underground, and making an estimate of the depth to bed rock where it is concealed. This is possible by observing the distribution of ledges and the appearance of the topography. It is often possible to detect where the pre-glacial stream courses were before their drainage was disarranged by the glacial drift. Having decided where the streams used to go, the approximate depth to bed rock in the present stream courses can then be predicted, and these estimates have been of great help in making preliminary investigations of dam sites. In one case I examined a dam site in a rocky gorge where none of the engineers suspected a great depth to rock, but we proved by electrical prospecting that it was over 100 feet to bed rock, a short distance above the dam site. The extremely rugged topography at the dam site made it impossible to use the electrical method there. The air pictures convinced me that the pre-glacial stream did not

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go through this narrow gorge, but went off to one side, and that its course is now blocked by high hills of glacial drift. Of course this conclusion will have to be checked by drilling, but the information was a great help in making the preliminary study.

I have also found that viewing the country from the air is very useful, and that in combination with the study of air pictures a good understanding of the topography can be obtained. By making a reconnaissance flight before the air photography is begun, it is possible to select those regions where the air pictures are most needed and avoid photographing sections of the country which do not concern the problem.

Aerial photography is a new tool for the geologist which will enable him to give more information to the engineer.

FRANK O. WHITNEY: * I have been much interested in the discussion tonight, and particularly in the work Professor Spofford is doing for the city of Boston, because of my past experience. It is true, as he says, that we have not an accurate map of the city. We have several things that serve the purpose fairly well, but as this process of aerial mapping has been described, it seems to me that something of value may be accomplished in this way. For instance, with the aid of the aerial survey, I can see how quite an accurate map of the streets of Boston can result, and if this can be enlarged in certain territories to a scale of 50 feet to the inch, I can see how a very useful map of the sections can be produced for the use of the assessors and other departments. If it is expected, however, that unassessed property will be discovered by this method, I don't believe that even with a map on a scale of 50 feet to the inch any material differences will be discovered in the assessment of property. This is a subject I have had a great deal to do with during the last twenty-five or thirty years. I was chief engineer of the street laying-out department for twenty-five years before my retirement, and had quite a large force of men, who in certain seasons, when they were not fully employed, were occupied in making surveys in the congested part of the city, to try to discover unassessed property.

PROFESSOR SPOFFORD: I should like to say a few words in reply to Mr. Whitney's remarks. The object of the aerial survey is not primarily that of finding property not now assessed. If we do find some buildings and areas not included in the assessors' lists it will add to the value of the survey, but its primary purpose is, as has already been explained, to obtain a complete set of lot-and-block plans, including the recently annexed Hyde Park district, for use of the assessors.

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Specifications for an Aerial Photographic Survey of the City of Boston accompanying Discussion by Charles M. Spofford

1. *Area to be Mapped*

The total area to be mapped is a certain part of the city of Boston designated as Area A, or a certain part of the city of Boston designated as Area B, or the whole of the city of Boston excepting certain islands in Boston Harbor, designated as the Areas A and B combined.* The total area contains approximately 47.5 square miles, and is divided into two portions shown as Area A and Area B on the accompanying map of the city of Boston, prepared by the Planning Board and dated November, 1926.

Area A comprises East Boston, South Boston, Charlestown, the downtown business district and a portion of the Back Bay district. This area is indicated by red ink cross-hatching, and is approximately bounded southwesterly by Massachusetts Avenue and southerly by Southampton Street to Columbus Park, and the extension thereof to the harbor. The area is approximately 12.9 square miles.

Area B is largely residential and comprises the remainder of the city of Boston. This area is indicated by green ink cross-hatching, and is approximately 34.6 square miles.

Areas A and B combined are the summation of Area A and Area B.*

2. *Work to be Done*

The contractor is to make an aerial survey of the area described as Area A or as Area B or as Areas A and B combined in Article I of these Specifications, prepare mosaic maps of the same, and furnish the city with photographs all in accordance with the requirements set forth hereinafter in these Specifications.

3. *Description of Work to be Done on Area A*

This area is to be surveyed in such manner as is required to prepare and furnish the following photographic prints, plans and maps:

(a) One (1) contact print of each aerial negative on double-weight, black and white photographic paper having a semi-matte finish, each to be to a scale of one (1) inch equals approximately 250 feet. A complete set of these contact prints shall be delivered to the city within ten (10) days after all flying operations of the contractor, covering Area A, are completed.

(b) The location of each aerial negative upon a map of the city of Boston to be furnished by the city.

(c) One (1) photographic copy of a mosaic map to a scale of one (1) inch equals 500 feet upon which is designated the location of each aerial negative.

(d) A set of photographic enlargement sheets corresponding to areas shown on the mosaic map to a scale of one (1) inch equals fifty (50) feet on double-weight,

* The contract was awarded for Areas A and B combined.

black and white photographic paper having a semi-matte finish, each sheet to be twenty-four (24) inches in width by thirty (30) inches in length, and to have a clear margin of two (2) inches at the left end and a clear margin of one (1) inch on all other sides. The area to be shown on each sheet is to be designated by the chairman on the mosaic map, and the attention of bidders is called to the fact that the areas so designated may overlap each other in order that the area shown on each sheet may conform to street or other convenient boundaries.

(e) One (1) photographic copy of a mosaic map to a scale of one (1) inch equals five hundred (500) feet upon which is designated the location of each photographic enlargement sheet.

4. *Description of Work to be Done on Area B*

This area is to be surveyed in such manner as is required to prepare and furnish the following photographic prints, plans and maps:

(a) One (1) contact print of each aerial negative on double-weight, black and white photographic paper having a semi-matte finish, each to be to a scale of one (1) inch equals approximately five hundred (500) feet. A complete set of these contact prints shall be delivered to the city within ten (10) days after all flying operations of the contractor, covering Area B, are completed.

(b) The location of each aerial negative upon a map of the city of Boston to be furnished by the city.

(c) One (1) photographic copy of a mosaic map to a scale of one (1) inch equals eight hundred (800) feet upon which is designated the location of each aerial negative.

(d) A set of photographic enlargement sheets corresponding to areas shown on the mosaic map to a scale of one (1) inch equals one hundred (100) feet, on double-weight, black and white photographic paper having a semi-matte finish, each sheet to be twenty-four (24) inches in width by thirty (30) inches in length, and to have a clear margin of one (1) inch at the left end and a clear margin of one-half ($\frac{1}{2}$) inch on all other sides. The area to be shown on each sheet is to be designated by the chairman on the mosaic map, and the attention of bidders is called to the fact that the areas so designated may overlap each other in order that the area shown on each sheet may conform to street or other convenient boundaries.

(e) One (1) photographic copy of a mosaic map to a scale of one (1) inch equals five hundred (500) feet upon which is designated the location of each photographic enlargement sheet.

5. *Mosaic Map*

Each area is to be surveyed in such manner as is required to prepare and furnish the mosaic map described below:

One (1) mosaic map of Area A or Area B or Areas A and B combined on double-weight, black and white photographic paper having a semi-matte finish and to a scale of one (1) inch equals five hundred (500) feet. Such captions and titles as may be desired upon this map will be specified later by the chairman and shall be placed on the map by the contractor.

6. *Control needed for, and Accuracy of, Aerial Photographic Maps and Photographic Enlargements*

The city shall furnish, within twenty (20) days after delivery to it of contact prints, such control distances as the contractor may need to enable him to conform to the following requirements:

The accuracy of the mosaic map or any photographic enlargement sheet or combination of sheets shall be such that the horizontal ground distances as obtained by direct measurements between control points on the mosaic map or on the photographic enlargement sheets shall be equal to the control distances; and the distances between other points shall not be in error more than two (2) per cent of the actual distances between points on Area A, or one (1) per cent of the actual distances between points on Area B.

The control distances to be furnished by the chairman shall consist of:

Distances between objects identifiable on contact prints. Control distances shall be furnished by the chairman for not less than two contact prints on any strip flown; and for not less than every fifth print on each strip. Such control distances will be given on the backs of the contact prints, which will be so marked as to indicate measurements between objects identifiable thereon, and shall cover a distance represented by not less than three (3) inches, and need not be greater than five (5) inches in length on the prints, and should be so placed that the perpendicular distance from the center of the print to the control measurement is not more than two (2) inches measured on the print.

If any point selected as the end of a control distance be difficult to identify on the print, then the chairman shall diagram such point in a sketch, not necessarily to scale, on the back of the contact print. The approximate difference of elevations between the two control points, which are the ends of a control measurement, shall be furnished by the chairman. Any elevations given shall refer to the Datum Plane used by the Engineering Department of the city of Boston.

7. *Experience and Equipment of the Bidder*

Each bidder will be required to show what experience he has had in this class of work, and to present references from responsible parties familiar with his work, and further, to show that he has a sufficiently large and up-to-date plant and equipment to complete properly the requirements of the contract as called for, and that he has a competent and complete engineering staff and adequate ratio projecting and copying cameras and lenses so that the finished enlargements may be made satisfactorily and to scale.

Each bidder must be ready to show the chairman, or such person as he may designate, his plant, and explain his methods of production.

Failure by any bidder to satisfy the chairman that he has an experienced organization, an adequate equipment and sufficient capital and resources to ensure the successful carrying out of the proposed contract will mean that his bid may be rejected even if it is the lowest submitted.

8. *Prosecution of Work*

Unless it be decided by the chairman that the shadows in the district included in Area A are so excessive that sufficiently clear and sharply defined contact prints cannot be obtained, the contractor will be required to start producing the original aerial negatives necessary to cover Area A within one (1) week after the contract is awarded, and to complete the production of the aerial negatives on or before October 10, 1929.

In the case of excessive shadows in Area A, the chairman may extend the time of starting to take these negatives to any date before August 1, 1930, and the production of these negatives is to be completed within thirty (30) days after this extended date of starting to obtain negatives.

The original negatives covering Area B shall be completed on or before December 1, 1929, but the taking of negatives for portions of this area containing considerable foliage shall be delayed as late as possible consistent with completion of the work prior to this date.

Should unfavorable flying and photographic weather conditions prevail in any of the above cases, the time may be extended by the chairman.

It is assumed in the above cases that the contract will be awarded on or before September 10, 1929.

The contractor shall, at all times during the progress of the work, maintain an airplane with photographic crew and all necessary equipment in readiness to take advantage of all suitable weather conditions.

9. *Obtaining Negatives and Photographic Quality of Product*

The camera used in this work may be of any type of American aerial camera approved by the chairman, the focal length of the lens shall be not less than twenty (20) inches, and the size of the original negatives not less than approximately seven and one-half ($7\frac{1}{2}$) inches by nine and one-half ($9\frac{1}{2}$) inches.

The maximum tilt of the camera from a horizontal plane shall not exceed two (2) degrees.

The negatives shall be so made that the angle between a straight line representing the average line of flight of any strip and the short side of each negative, the direction of which side approximates that of the line of flight, shall not be greater than fifteen (15) degrees.

The overlap of the negatives must be at least sixty (60) per cent along the line of flight, and fifty (50) per cent between the parallel lines of flight.

The original negatives must be taken under such conditions that they will be free from snow, clouds, cloud shadows, excess haze, stains, or other marks, and that each negative shall be of such photographic quality that a six diameter enlargement may be obtained without distortion.

The quality and tone of the photographs shall be clear and sharp in detail and contain equal color value, comparable to samples submitted by the bidder. Bidder

will submit both contact prints and photographic enlargement sheets as samples conforming with the specifications of prints to be delivered.

10. *Rejections*

The chairman reserves the right to reject and cause to be made over any photographic negative or photographic print that is not made in accordance with the above specifications.

11. *Rights in Negatives*

All negatives involved in the work to be done under this contract shall become the property of the city.

12. *Publication by Contractor*

No copies of aerial photographs are to be made without consent of the chairman, but the contractor will be permitted to reproduce copies of the mosaic maps for public sale.

OF GENERAL INTEREST

FALL MEETING OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the Boston Society of Civil Engineers, who had an opportunity to attend technical sessions of the fall meeting of the American Society of Civil Engineers, held in Boston on October 10 and 11, found much of interest in the matters discussed relating to projects and undertakings in the metropolitan area about Boston.

The program prepared for this meeting evidently made an unusually definite appeal to the members of the American Society, witnessed by the fact that there were more than 800 registrations at these meetings.

As an expression of interest and with the thought of extending a welcome from the Boston Society of Civil Engineers, the oldest Engineering Society in the country, the officers and past presidents of the Boston Society gave an informal dinner, at the Engineers Club, on the evening of October 8, to the Board of Direction of the American Society of Civil Engineers. This event, at which the ladies, also, were present, proved to be a very enjoyable affair.

Mr. Frank E. Winsor, President of the Boston Society of Civil Engineers, presided at the dinner, at which there were 79 attending.

Tidal Bench Marks

The descriptions and elevations of more than 200 well-defined bench

marks, which have been used by the United States Coast and Geodetic Survey in its tidal and hydrographic work along the coast of Massachusetts, have been assembled and published recently. The elevation of these bench marks is given with reference to the various tidal datum planes.

Copies of this publication may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

Freeman Fund Traveling Fellow in Brno, Czechoslo- vakia

The Freeman Fund Traveling Fellow, Mr. Samuel Shulits, writes briefly to the Secretary regarding foreign study:

Just a little personal report of my activities. I have been in Brünn (this is the German name of the city, while Brno is the Czech name) for some time with Professor Schoklitsch, who has given me an office with a couple of tables in his headquarters at the Technische Hochschule.

The laboratory here will soon be ready for operation, and all of us, Professor Schoklitsch, his two assistants and I, are working in the laboratory to rush things along. The little tricks of the trade during the setting up of the laboratory that I am noticing will always be of value in hydraulic laboratory practice. In a little while we will be

turning out experiments. Schoklitsch is a dynamo of enthusiastic energy. He is an engineer and educator of considerable repute in Europe, especially in the field of research concerning the motion detritus in streams, a very important question not only in model studies, but also in the modern studies of river flow.

Here in Brno it took some time to find a convenient place to live. European baggage transport on the trains is not what it might be, and so my baggage containing notes for a report or two did not arrive until a short while ago.

In the meantime the editor of "Wasserkraft und Wasserwirtschaft," one of the leading periodicals in hydraulic engineering in Europe, asked me to write him a German résumé of the article in the "Engineering News-Record" on the Bonnet Carré Spillway. I postponed the writing of the report in the belief that such an article would bring to the attention of European engineers

the work of American Engineers, and would also acquaint them with the purpose of the Freeman Fellowship and the name of our Society. I have always kept the latter aims in view during my stay in Europe.

The status of the European professor is enviable. The educational institutions function under the government. Once appointed, a professor cannot be discharged. He can hold his position until retired with a rather fair pension. The professors are generally chosen from the prominent engineers between the ages of thirty-five and fifty. The slow academic climb by gradual promotion from assistant to a professor to a professorship is also encountered. At the time of a vacancy the faculty chooses the successor. The rector of the college or the president is chosen by the members of the faculty from its own numbers, and he is really an honored man with full executive powers. How different from the United States!

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Sanitary Section

NOVEMBER 6, 1929. — Preceding the meeting twenty-two members attended dinner at Patten's restaurant.

The meeting of the Sanitary Section was held at 7.20 P.M. The Chairman called the meeting to order and introduced Mr. E. Sherman Chase of Metcalf & Eddy, Consulting Engineers, who spoke on "The Effect of Industrial Wastes on Sewage Disposal Plants, with Especial Reference to Fostoria, Ohio."

The paper was discussed by Messrs. Burden, Coburn, Haley, Porter and Wright. The meeting of twenty-seven members adjourned at 8.20 P.M.

GEORGE G. BOGREN, *Clerk*.

Highway Section

OCTOBER 16, 1929. — The Highway Section met at the easterly end of Soldiers Field Road, an extension of Bay State Road, near Cottage Farm Bridge, at 2.30 P.M. on Wednesday, October 16 for an inspection of several parkway extensions of considerable importance, which were outlined briefly by the Chairman, Prof. Charles B. Breed.

The group proceeded along Soldiers Field Road, a bituminous macadam roadway to Western Avenue. At this point the granite block edging and other features of the road were inspected and discussed. Mr. Edwin H. Rogers, Chief Engineer of the Parks Division of the Metropolitan District Commission, described some of the features of this work. The party con-

tinued along the existing section of Soldiers Field Road and across the Larz Anderson Bridge to Fresh Pond Parkway. A stop was made here while Mr. Raymond W. Coburn, Construction Engineer, Massachusetts Department of Public Works, which is building this road, explained the new route which Alewife Brook Parkway Extension would provide, that is, a connecting link between Fresh Pond Parkway in Cambridge and Alewife Brook Parkway.

The inspection group then proceeded to Alewife Brook Parkway Extension in Cambridge, where most of the time was spent watching operations at the site of the new steel truss bridge which spans the Fitchburg Division of the Boston & Maine Railroad.

The remaining time was employed in inspecting the subgrade of the roadway, and at the site of the new bridge spanning the Central Massachusetts Division of the Boston & Maine Railroad.

Fifteen attended the inspection trip. The trip was completed at 4.30 P.M.

ERNEST MATHERS, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[November 20, 1929]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names

of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

For Admission

CHANDLER, PAUL R., Wollaston, Mass. (Age 20, b. New Hampton, N. H.) Student at Northeastern University, and during the co-operative periods has been employed ten weeks as rodman and five months as transitman for Whitman & Howard, and also as transitman five months for E. W. Branch, Quincy. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, C. A. White.*

CHAPUT, ROLAND R., Haverhill, Mass. (Age 28, b. Haverhill, Mass.) Student at Northeastern University, in class of 1930, and during co-operative periods has been employed by the Land Court since 1927. Refers to *H. B. Alword, C. O. Baird, C. B. Humphrey, J. W. Ingalls, W. E. Nightingale.*

EDSON, RAYMOND E., Swampscott, Mass. (Age 21, b. East Lynn, Mass.) Student at Northeastern University, and during the co-operative periods has been employed by Henry F. Bryant & Son, Simpson Brothers, General Contractors, and Willcut Construction Company of Boston. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, W. E. Nightingale, C. A. White.*

GREENE, CARLE WHITTIER, Melrose, Mass. (Age 25, b. Melrose, Mass.) Education: four years in Technical High School, three years' private instruction in structural drafting and engineering, and at present enrolled at Lowell Institute in buildings course. Experience: June, 1926, to June, 1929, employed by Wilson Engineering Corporation of Cambridge as checker of drawings and designs submitted by students of correspondence courses, and as structural detailer; November, 1928, to March, 1929, after hours, structural draftsman with Cleverdon, Varney & Pike; June, 1929, to date, with New England Power Construction Company. Refers to *D. E. Moore, W. F. Pike, Trygve Rusteveldt, E. A. Varney.*

GORBELL, GEORGE LEIGHTON, Everett, Mass. (Age 20, b. Everett, Mass.) Entered Northeastern University in September, 1927, and during co-operative periods has worked in the engineering department, city of Waltham, starting as a rodman and now a transitman. Refers to *H. B. Alword, H. L. Burton, J. W. Ingalls, W. E. Nightingale*.

GUILD, ARNOLD L., Roslindale, Mass. (Age 20, b. Roslindale, Mass.) Student at Northeastern University, and during co-operative periods has been employed by E. M. Brooks of Newtonville, Mass. Refers to *H. B. Alword, C. O. Baird, J. W. Ingalls, W. E. Nightingale*.

LINCOLN, FRANK LOUIS, Arlington Heights, Mass. (Age 26, b. Portland, Me.) Graduate of University of Maine with degree of B.S. in civil engineering in 1925. Worked holidays and vacations as chainman, rodman and instrumentman; also chief of party for Bangor & Aroostook Railroad from 1919 to 1925. From June, 1925, to February, 1926, was instrument man and inspector on construction of wharf at Searsport, Me.; from February, 1926, to date in the office of Fay, Spofford & Thorndike, on survey, design and resident engineering work on waterfront terminal, railroad, bridge, water supply, etc. Refers to *C. A. Farwell, G. B. Griffin, R. W. Horne, W. H. Sears, L. B. Turner*.

LOCKERBIE, ALFRED AIKEN, Marblehead, Mass. (Age 22, b. Marblehead, Mass.) Entered Northeastern University in the fall of 1927, and during co-operative periods has worked for Newell B. Snow, County Engineer, Barnstable; also with the Boston & Maine Railroad, under S. H. Scribner, Assistant Division Engineer, Dover, N. H. Refers to *H. B. Alword, G. B. Gee, J. W. Ingalls, G. H. Meserve*.

LOVE, THEODORE RUFUS, Natick, Mass. (Age 21, b. Natick, Mass.) In October, 1926, entered the employ of the engineering department of the town of Framingham as a rodman, and in January, 1927, entered Northeastern University. Since that time, during co-operative periods, has still been employed by the town of Framingham. Refers to *H. B. Alword, C. O. Baird, H. L. Burton, F. F. Hampe, J. W. Ingalls*.

MURPHY, RICHARD DAVIS, Lynn, Mass. (Age 22, b. Lynn, Mass.) Graduate of Lynn Classical High School and now a student at Northeastern University. During co-operative periods has been employed by Shay & Shay, civil engineers, Lynn, and Whitman & Howard. Refers to *C. O. Baird, Jr., Channing Howard, J. W. Ingalls, W. E. Nightingale*.

SOROKA, MARY OLGA, Cambridge, Mass. (Age 25, b. New York, N. Y.) Graduate of Massachusetts Institute of Technology, 1926, with degree of S.B. in civil engineering; October, 1926, to February, 1927, draftsman, North Jersey Transit Commission, Jersey City, N. J.; February, 1927, to April, 1928, structural steel draftsman, Purdy & Henderson, New York City; April, 1928, to February, 1929, engineer, design and construction of underpinning, Spencer, White & Prentiss, New York City; February, 1929, to July, 1929, research assistant in hydraulic and sanitary engineering, University of Wisconsin, Madison, Wis.; July, 1929, to September, 1929, engineer, structural steel design, H. G. Balcom, New York City; September, 1929, to date, engineer, hydraulic division, Stone & Webster Engineering Corporation. Refers to *G. L. Hosmer, T. B. Parker, G. E. Russell, C. M. Spofford*.

WHITE, PHILIP DAWSON, Belmont, Mass. (Age 21, b. Cambridge, Mass.) Graduate of Belmont High School and entered Northeastern University in September, 1927. During co-operative periods has been employed by Howland H. Barnes and Henry F. Beal of Newton and Waltham. Refers to *H. B. Alword, C. O. Baird, Henry Brask, J. W. Ingalls*.

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THEODORE W. HOMKOWYCZ, 43 Brooksdale Road, Brighton, Mass.

DEATHS

LEMUEL POPE . . . died Oct. 31, 1929
HERBERT F. PIERCE died Oct. 27, 1929

BOSTON SOCIETY OF CIVIL ENGINEERS

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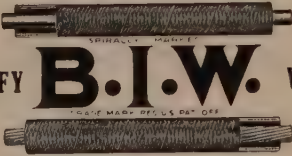
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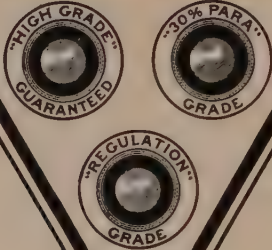
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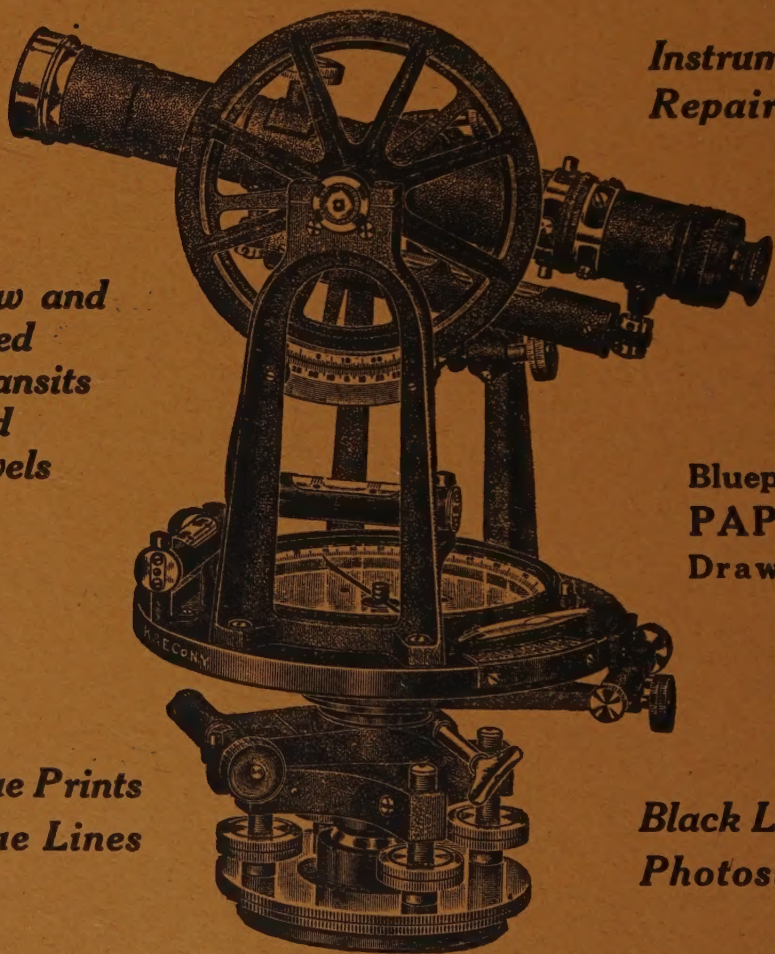
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